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ABSTRACT

Simple observation of dance movement, while very useful, can lead to misconceptions, about the physical realities of dance movement, that make learning difficult. This gap between reality and understanding can be reduced by the application of biomechanical techniques such as cinematography, electromyography, and force-plate analysis. Biomechanical analysis has proved a useful tool in many fields, but its use in studying dance movement has been very limited. The few studies that have been conducted concern posture, jumping, turning, kicking, bending the knees with or without holding a barre, and standing on tip-toe. Such studies in dance have been confined to ballet, because the movements in ballet are more stylized, and therefore more easily analyzed. While biomechanical analysis helps in the understanding of dance, it has also been found that dance helps in the understanding of biomechanics. There are many more dance movements in ballet awaiting investigation, and beyond that waits the still more difficult analysis of modern and ethnic dance. (CJ)

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THE VALUE OF BIOMECHANICAL RESEARCH IN DANCE"*

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Dance is an art form as well as an athletic skill. As such it demands an ability to perform, and at the same time, maintain an aesthetically pleasing posture. To do both may require the artist to create an illusion. She may have to appear to defy the laws of physics, yet at the same time use these laws to create the effect.

Simple observation of movement, while very useful, can lead to misconceptions about the physical realities of movement that make learning difficult. The gap between the reality and our understanding of it can be reduced by the application of biomechanical techniques. Such techniques include cinematography, electromyography, and force-plate analysis:

1. Cinematography, after application of strategically located body markers allows us to clearly define the movement of chosen body segments so as to unmask the illusion.

2. Electromyography tells us what muscles are producing the movement, indicating wide variation from subject to subject.

3. Force-plate analysis allows us to quantify the forces generated and calculate energy requirements. Computers facilitate the analytical process in a very necessary way.

Biomechanical analysis has proved a useful tool in many fields but its use in studying dance movement has been very limited. The few studies that have been done concern posture, jumping, turning, jumping and turning, kicking, bending the knees with and without holding the barre, and standing on tip-toe. Such studies in dance have been confined to ballet, because the movements in ballet are more stylized, and therefore more easily analyzed.

As scientists we must approach dance with humility. Four centuries of instruction in classical ballet (for example) cannot be all wrong. On the contrary it has succeeded - and at that quite well! Our object is to find out why it has succeeded ("How in the world do they do it?"), and in so doing improve the teaching of dance and ultimately the quality of performance, where this may be possible.

Based on a paper presented at the American Alliance of Health, Physical Education, Recreation and Dance Conference, Houston, April 26, 1982, entitled "How in the world do they do it?".

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The importance of body alignment is well recognized by dancers as the necessary starting point for all movement. The body must be correctly centered. As Wilson[10] has pointed out this implies an awareness of the location of one's center of gravity. Thus in discussions of centering we find dancers possess concepts which are scientifically correct but expressed in nonscientific terms. So what? It does not matter what words are used as long as the concept can be correctly transmitted through them.

At other times we find dance instruction may be correct, but due to lack of understanding of physical laws, inappropriate imagery is used and the learner may become confused. Lawson[5] states in "Teaching Young Dancers" that in performing a vertical jump, after filling the lungs with air to make the body lighter, the arms which are intially above the head should be brought down so as to create a vacuum into which the body rises. When common sense tells the novice this cannot be true, learning may be inhibited.

Various forms of jeté have been studied biomechanically by Ryman and by Laws. Ryman[6] studied 6 selected "grand allegro jumps" performed by one soloist with the National Ballet of Canada who was simultaneously assessed by two ballet teachers to be correctly executing the movements in accordance with balletic conventions. Her cinematography revealed that while the center of gravity rises and falls along a parabollic curve the head can be kept near the top of the curve longer if during the jump the arms are brought quickly downward.

The body's center of gravity is at a lower point within the body when the arms are down at the sides. Bringing the raised hands down after reaching the height of the jump allows the trunk and head to remain up while the center of gravity is falling (Figure 1).

Laws[4], agreeing with Ryman, went on further to state that even without any upper limb movement, because the center of mass follows a parabollic curve, even a ball thrown up in the air, spends half of the time it is in the air within the upper 25% of its vertical height. It must slow down and stop before changing direction, and this takes time.

Instruction based on the <u>appearance</u> of the illusion does not help the student learn how to create the illusion, and may even inhibit learning. Laws' study of the pirouette is a good example.[3] He used the principles of rotational mechanics in analyzing pirouettes performed by one dancer with the New York City Ballet. He studied the role of the push-off foot and the supporting foot in exerting the initial torque, the relative magnitudes of angular momentum in different types of turns and the dependence of angular velocity on distribution of body mass.

One of his conclusions was that, although it is easier to turn en pointe because the toe of the shoe, with its smaller surface area, offers less frictional resistance to turning, the instruction to "go up and then turn" is really a description of an illusion. The force required to generate the turn must be applied against the floor before going up creating angular momentum. Then by bringing the arms in toward the center of rotation the velocity of rotation is increased.

The same principle applies when the dancer jumps and turns. Vaganova[8] stated that in the tour jeté, rotation of the torso should occur after the apex of the jump is reached. But Hinson et al[2] have shown in a study of three dancers that the twisting motion must be initiated before leaving the supporting surface. The trick is in not making it obvious.

Ryman[6] in a more detailed study of one professional dancer demonstrated how the turn was initiated during the push-off phase, and followed through. The lower torso and legs rotated through half of the required 180° prior to take off, in advance of rotation of the upper part of the body arms and head. Then at the apex of the jump, bringing the extended limbs close to the axis of rotation accelerated the turn. The limbs were re-extended in the final position. The whole event occurred so quickly that the details were not apparent unless scientifically analyzed.

Our work at Waterloo[7], studying the Grand Battement Devant performed by 12 senior students from two internationally famous ballet schools produced several examples of instructions given which are based on visual impressions but if obeyed prevented an ideal performance. Dancers are taught to keep the "buttock muscles tight" and thus maintain a good turnout while executing a forward kick. However, the gluteus maximus, a powerful hip extensor and external rotator, must relax toward the end of of the kick to allow maximum elevation of the foot. In all cases it did relax, allowing the foot to rotate inward to the neutral position just at the height of the kick. This rotation, imperceptible to the unaided eye, coupled with some degree of knee hyperextension, increased considerably the apparent height of the kick. But keeping gluteus maximus on too long in one instance reduced that particular kick by 20 degrees.

Also, contrary to current teachings, the pelvis rotated upward during the kick an average of 30 degrees, and considerable activity was noted in the support leg. Both these events contributed to a higher kick, but were invisible to the eye. Such is the art of ballet. But should the dancer and her teacher be unaware of how this is accomplished? When the magician performs feats of magic, we know it is done by sleight of hand but still admire his artistry. How can he learn to do these tricks if he really believes they are performed through magic? What applies to sleight of hand also applies in dance to sleight of foot.

Both published and unpublished research on the plié, with or without use of the barre, has been carried out. But more studies need to be performed before we can begin to understand what is really going on.

I would like to end my brief summary of biomechanical research in dance by referring to assessment of pointe work currently being done by Miss Vicki Galea[1] at the University of Waterloo because one of her findings allows us to view such research from a totally different perspective. So far we have seen that biomechanicians can help us understand and appreciate dance. Now I must tell you that dancers are helping us understand biomechanics.

In calculating forces acting around the ankle joint, when standing on points, it was found necessary to challenge the assumptions made by biomechanicians about the foot. The foot is modelled as one segment and measurements have been made of moments only around the ankle. Vicki, in addition to studying ankle moments, is examining force moments around metatarsophalangeal joints - so important in the production of foot deformities in dancers. In addition, because the dancer's foot is so flexible at the mid-foot level compared to that of a non-dancer, in this study the calcaneo-metatarsal angle changed from 150° to 86° in going to full pointe (Figure 2). This is of considerable significance in studying muscle length changes and velocity of contraction in dancers, and biomechanicians will need to consider whether this is necessary in other subjects also. Certainly the foot must now be modelled as two segments at least, and possibly three.

Through biomechanical studies of ballet we come to understand how the movements are really performed and how illusion is created. This may not make <u>me</u> able to dance but it does increase my admiration for those who do. With better understanding of how movements are produced there will be better teaching, and with that better performance. By examining the highly trained foot, biomechanicians become aware of its complexity, and who knows where the practical benefits of <u>this</u> knowledge will end? Truly, as Kenneth Laws[4,9] has said, physics and ballet make good partners - a new pas de deux.

There is much that still needs to be done. So far the studies have involved small groups or individual highly trained dancers. To determine whether the findings are representative of highly skilled performers the same experiments must be repeated using larger samples. In our own studies using 12 dancers we found very great individual differences even within a group of 4 who had similar body types and identical training together over several years. Against the background of the skilled performer we can then study the unskilled, to see what makes the difference. There are many more dance movements in ballet awaiting investigation, and schools of teaching that could be compared. And beyond that awaits the still more difficult analysis of modern and ethnic dance.

Why do we not do these wonderful things? Is it because those who can best do the investigations would rather study movement in sports - the jock mentality? Or are they rehab. snobs, looking down their noses at those who simply "entertain"?

Or does the fault lie with similar minded controllers of funding agencies? Our own work has been seriously hampered almost to destruction through lack of funds to analyze our data.

Perhaps a part of the problem may be a reluctance of dancers to have their artistry scrutinized by a scientist for fear he may discover they ae not really weightless sylphs, but human after all.

Unless we work together, the answer to my original question: "How in the world do they do it?" will be God only knows. But I am happy to say that at least we are beginning to learn.

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ABSTRACT

Biomechanical research in Dance has been limited to classical ballet. The primary findings are reviewed. Based on this review, such research is found to

1. increase our understanding of the movements
2. increase our appreciation of the artistry involved
3. provide better understanding, therefore better teaching
4. make possible better performance
5. Benefit biomechanicians

The challenge of further research is presented and the associated problems are briefly outlined.

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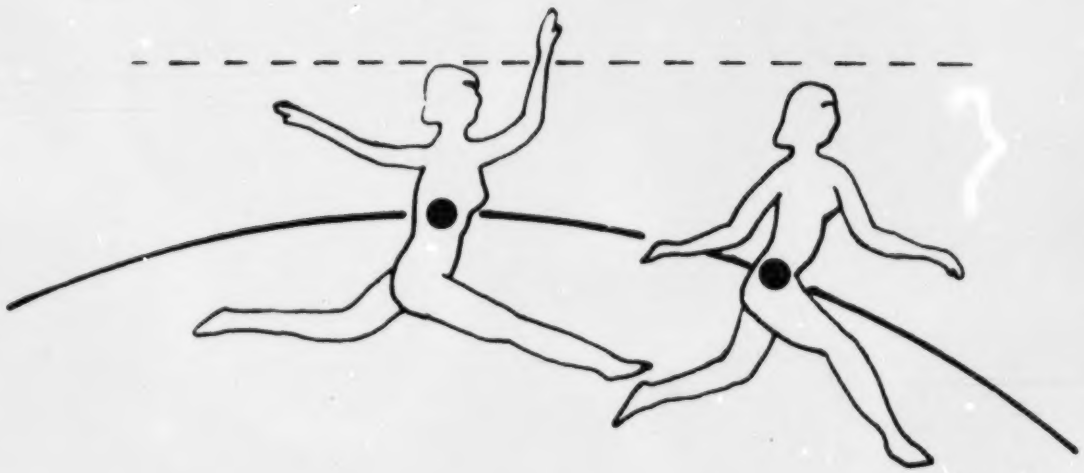
Figure 1 Lowering the arms allows the head to remain up longer while the center of gravity falls

Figure 2 The calcaneo-metatarsal angle (adapted from V. Galea)



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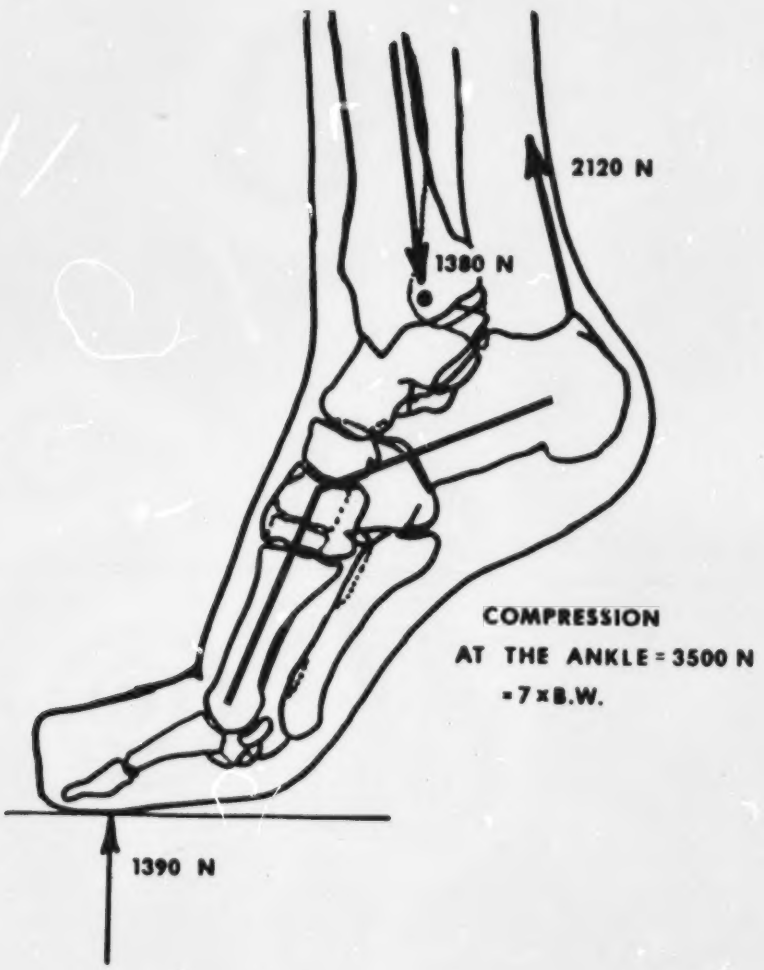

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